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Development of novel inorganic electrolytes to engineer rechargeable sodium batteries

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Over the last several years, research on rechargeable sodium ion or sodium metal batteries has received a great deal of attention as an alternative to lithium secondary batteries in energy storage for the electric grid. This is related to the considerable price reduction and the larger abundance of Na in the Earth´s crust in comparison to lithium. However, due to the size of the Na^+ ion (0.102 nm) compared to that of lithium ion (0.076 nm) and the poor electrochemical reversibility of sodium, it is difficult to find a suitable host material for reversible Na-ion or Na-metal storage. In addition, it seems necessary to develop new electrolytes capable to provide a non-dendritic and reversible plating/stripping of sodium as well as new candidates as active material capable to resist significant changes in volume in the cathode side.

The goal of this PhD thesis is to contribute to the development of sodium ion and sodium metal batteries. Our research focuses on the design on new inorganic and non-conventional electrolytes based on liquid ammonia [1]. These electrolytes have a concentration over 7 M in the sodium salt. This characteristic allows for a highly reversible electrochemical behavior of metallic sodium with an extremely fast kinetic of the process of plating/stripping as well as high stability of the sodium metal in the electrolyte. In addition, based on the outstanding performance of the sodium electrode, the sodium deposition on other metallic substrates with high reversibility is also possible. This advantage gives the possibility to assemble the device avoiding handling metallic sodium. Regarding the cathodic side, different materials have been studied. On the one hand, the possibility of using cathodes based on inorganic material such as amorphous titanium dioxide with different morphologies has been considered. These appear to be promising for rechargeable sodium batteries according to the bibliography, and it could be a suitable candidate for inorganic ammonia-based electrolytes. On the other hand, organic molecules could also be considered as active cathode materials. For instance, quinones and dyes could be promising electrodes for the inorganic electrolytes as they have a high theoretical capacitance. In addition, they could withstand significant changes in volume entailed by the process of insertion and deinsertion of sodium. Finally, the combination of the different elements described above can lead to the design of new rechargeable sodium batteries, which will have as main characteristics high power densities and gravimetric capacities, having the potential to be a competitive alternative to lithium-based batteries.

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